Preliminary Research Proposal (COE) (FY07)

TITLE:	Estuarine habitat and juvenile salmon – Current and historic linkages in the lower Columbia River and estuary
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Project Summary

Estuaries are considered important for the rearing of juvenile salmon and represent an integral component of the continuum of habitats that salmon occupy for significant periods of time. Recent analyses imply that the temporal and spatial patterns of estuarine rearing by juvenile Chinook salmon may have been simplified substantially compared with those of a century ago and that these changes are likely the result of a variety of human disturbances both upstream and within the estuary (Bottom et al. 2005). If this and other scientific assessments are correct (e.g., Williams et al. 2005), then reduced diversity of salmon life histories, including those dependent upon estuarine habitats, has diminished the resilience and productivity of salmon in the Columbia River Basin.

Information concerning what habitat attributes are needed to sustain diverse life histories of juvenile salmon are generally lacking in the Columbia River estuary, particularly in the tidal freshwater and oligohaline transition zones. Further, recent evidence supports the concern that flow in the Columbia River significantly affects the availability of estuarine habitats, that flow is much reduced compared with historic levels, and that seasonal flow patterns are much different now than a century ago. The long history of wetland loss in the Columbia River estuary coupled with change in flow patterns suggests that restoration of these habitats may benefit recovery of depressed salmon stocks. Yet no empirical studies of tidal wetland habitats have been conducted in the Columbia River estuary to assess their ecological functions or to establish their significance as rearing habitat for juvenile salmonids.

This proposal addresses specific information needs identified in our recent review of the effects of the Columbia River hydropower system on salmon habitat, particularly the recommendation to “monitor variations in life-history diversity, habitat use, and performance of juvenile salmon in the estuary” (Bottom et al. 2005). The ultimate goal of this research is *to define habitat protection and restoration priorities for the Columbia River estuary based on (a) the relationships between estuarine habitat conditions and the life-history diversity, abundance, and performance of juvenile salmon; and (b) the potential responses of salmonids to past and future habitat change.* Toward these ends, we propose (1) long-term monitoring to track variations in abundance and life histories of juvenile salmon in the Columbia River estuary and of the landscape features and physical factors associated with these patterns; (2) detailed evaluations of salmonid use of wetland habitats of various successional stages and of the factors

that influence development of these habitats and salmonid performance within them; and (3) evaluation of historic changes in river flow, sediment input, and habitat conditions in the estuary and the implications for juvenile salmon.

Our approach combines empirical monitoring of contemporary physical conditions, salmon-habitat associations, and life-histories with historical reconstruction of former estuarine habitat conditions. If we develop empirical associations between habitat attributes (e.g., salinity, depth, channel morphology, vegetation type, prey resources, etc.) and salmon distribution and performance (e.g., presence, abundance, residence time, and growth), then we can predict responses of juvenile salmon to physical change. This information is needed to establish criteria for restoring estuarine habitat.

This FY07 proposal outlines objectives and tasks that continue ongoing studies in the Columbia River estuary, which are now in their sixth year, including 5 full years of consistent data collection. Accomplishments to date include: (1) continuation of a monthly beach seine monitoring program at selected sites in the lower Columbia River and estuary (below Rkm 75) and addition of eight new seining sites in two regions of the mid estuary—Wallace Island (Rkm 77) and Lord Island (Rkm 101); (2) continued monthly trapnet sampling at an emergent wetland site at Russian Island, and at emergent/scrub-shrub/forested sites at Wallace Island and Lord Island; (3) If technically feasible, a mark-recapture study at Wallace or Lord Island sites using a remote PIT detection technique to estimate Chinook salmon residency; (4) A diel study to estimate consumption rates for juvenile Chinook salmon at Wallace or Lord Island if the mark-recapture study proves feasible; (5) continuous real-time physical monitoring at fixed stations in the Cathlamet Bay region to compliment similar data collected from a network of stations (CORIE) distributed throughout the lower estuary; (6) habitat classification and spatial analysis of historical datasets to characterize salmonid habitat conditions; and (7) continued analysis of historical temperature records to interpret trends in estuarine water temperatures and causal factors.

Background

Estuaries are the link between ocean feeding grounds and freshwater rearing habitats for anadromous salmon. Only recently have estuaries been recognized as potentially more important to adult and juvenile salmon than simply providing a physical migration corridor (Casillas 1999). However, the scientific information identifying the important elements of the estuarine ecosystem and how they function to facilitate salmon survival is sparse. Nevertheless, despite increased awareness of the importance of estuaries to salmon survival (Bradford 1995), research and management activities remain focused primarily on the freshwater phase of the salmon life cycle.

Information about salmon habitat requirements needed to evaluate potential effects of human modifications of the lower Columbia River and estuary is very limited. Most biological surveys in the Columbia River estuary have been conducted over short time intervals (a few years or less), involving a limited range of habitat types and site-specific locations. A variety of environmental studies have evaluated the effects of dredging and other development activities in the estuary. Many of these target sensitive benthic invertebrate assemblages but, with a few exceptions, provide little or no information about the linkages between invertebrate prey and fish predators or about the effects of anthropogenic changes on salmonid habitats and salmon growth or survival. Furthermore, fish surveys in the Columbia River estuary primarily have targeted mainstem and distributary channel margins, which are heavily used by larger yearling ("stream-type") salmon migrants, including hatchery fish, which tend to migrate rapidly through the estuary to the ocean. Most surveys in the lower Columbia river have ignored shallow wetlands, forested swamps, sloughs, and other backwaters that may be among the principal habitats for small subyearling ("ocean-type") salmon that often rear in estuaries for extended periods (Reimers 1973). A long-term monitoring and evaluation program is needed (1) to insure that planned anthropogenic modifications of the Columbia River (either upstream or downstream from the dams) do not adversely affect estuarine-rearing salmonids in critical shallow water habitats; and (2) to develop criteria and a process for selecting, designing, and evaluating restoration projects based on their potential benefits to salmon rearing habitats and life-history diversity.

Research indicates that shallow, low-velocity estuarine habitats are particularly productive rearing areas for a variety of Pacific salmon species and life-history types (e.g., Levy and

Northcote 1982, Levy et al. 1979). Life-history diversity within and among salmon species is reflected in varying times and sizes of entry to the estuary, periods of estuarine residence, habitat and microhabitat distribution, diet, and growth rates. In river-dominated systems like the Fraser and Columbia River estuaries, emergent and forested wetlands and their networks of shallow, dendritic channels and backwater sloughs offer refugia for small juvenile salmon from the strong current velocities of main river channels. Of particular concern for Columbia River salmon are the extensive tidal freshwater and oligohaline wetlands that encompass a critical staging area and transition zone, particularly for small subyearling salmon when they first encounter and must acclimate to salt water. Cathlamet Bay is an example of this transition area. The off-channel habitat complex within these transition zones constitutes biologically sensitive areas where small changes in salinity distribution could substantially affect the salmon rearing capacity of the estuary.

Unfortunately, 62% and 77% percent, respectively, of the historical emergent and forested wetlands of the Columbia River estuary have been lost to diking and filling (Sherwood et al. 1990; Thomas 1983) and may have substantially decreased the capacity of the Columbia River estuary to rear salmon. Substantial wetland losses also may reduce population diversity in the basin by removing habitats needed to support those salmon species and stocks with subyearling life histories. Despite increased interest in restoring tidal wetlands in the Columbia River estuary, in part to improve conditions for all declining salmon stocks, the specific features of salmon habitats that need to be re-established or that dredging or other management activities must protect remain poorly defined.

The importance of flow as a factor influencing habitat for juvenile salmon is receiving increased attention. Recent evidence evaluating changes in flow and bathymetry in the lower Columbia River and estuary show strong, correlations between river discharge and availability of juvenile salmon habitats. This correlation is often very distinct between modern and pre-development conditions in the Columbia River estuary, as well as among different sub-regions of the estuary (Bottom et al. 2005). In addition, available evidence suggests that historical flow patterns through the Columbia River estuary differed markedly from present-day conditions. Total annual flows are significantly reduced, spring freshets occur earlier, and winter flows are higher while those in the summer are much lower relative to historical patterns (Bottom et al. 2005). Understanding the effects of flow and other physical factors on salmon rearing opportunities in the estuary is important to devise management strategies that will aid salmon recovery.

Research Goal

This proposal addresses specific information needs identified in our recent review of the effects of the Columbia River hydropower system on salmon habitat, particularly the recommendation to "monitor variations in life-history diversity, habitat use, and performance of juvenile salmon in the estuary" (Bottom et al. 2005). The ultimate goal of this research is *to define habitat protection and restoration priorities for the Columbia River estuary by determining (a) the relationships between estuarine habitat conditions and the life-history diversity, abundance, and performance of juvenile salmon; and (b) the potential salmonid responses to past and future habitat change.* Toward these ends, we propose (1) long-term monitoring to track variations in abundance and life histories of juvenile salmon in the Columbia River estuary and of the landscape features and physical factors associated with these patterns; (2) detailed evaluations of salmonid use of wetland habitats of various successional stages and of the factors that influence development of these habitats and salmonid performance within them; and (3) evaluation of historic changes in river flow, sediment input, and habitat conditions in the estuary and the implications for juvenile salmon.

Approach

This proposal addresses factors at two important scales that determine the qualities of essential fish habitat and the performance of salmon. At the landscape scale, the estuary-wide distribution of habitats coupled to salmon migration behaviors determines whether individuals can readily access available habitats. For example, many studies have shown that salmonid movements and habitat use within estuaries are size-related. Small Chinook and chum salmon subyearlings (fry) usually occupy shallow, nearshore habitats, including salt marshes, tidal creeks, and intertidal flats (Levy and Northcote 1982; Myers and Horton 1982; Simenstad et al. 1982; Levings et al. 1986). As subyearling salmon grow to fingerling and smolt stages, their distribution typically shifts toward deeper habitats farther from the shoreline (Healey 1982, 1991; Myers and Horton 1982). Landscape-scale monitoring is necessary to interpret whether the migratory pathways and distribution of juvenile salmon of various sizes and life histories affect their ability to access and benefit from available estuarine rearing habitats.

At a finer scale, juvenile salmon performance is determined by physical and biological conditions and ecological interactions within particular habitats. Local differences in prey availability, water temperature, and habitat complexity, for example, ultimately determine salmonid feeding success, growth rates, and survival during estuarine residency. The local conditions and interactions within a habitat, in turn, may also depend on the geographic location and position of each habitat along the estuarine tidal gradient. For example, similar types of habitat in different estuarine locations may function differently due to tidal and riverine influences on temperature and salinity ranges or the abundance and composition of prey resources. In this way, understanding of local habitat linkages to salmon also requires reference to the larger landscape features within which each habitat is embedded. This proposal combines monitoring of salmon abundance, life histories, and habitat use at a broad landscape scale with detailed assessment of the ecological interactions affecting salmon within a variety of wetland habitat types.

We propose to develop our understanding of how the estuary currently and historically benefited juvenile salmon by determining salmonid distributions (presence/absence and abundance) and performance in relation to specific habitat attributes. Regions of particular interest include shallow water areas either adjacent to peripheral forests and wetlands or centrally located in the river, dendritic and channel margins, and sloughs. We also will place salmon-habitat associations in a historical context by evaluating river discharges and sediment inputs into the estuary for the past 100 years and reconstructing past and present availability of salmon habitat through the lower Columbia River and estuary using GIS mapping.

Objectives and Tasks

Objective 1. Compare trends in abundance and life histories of juvenile salmon at a landscape scale for representative shallow water habitats between Bonneville Dam and the Columbia River mouth.

Juvenile salmonids originating from upland freshwater spawning grounds in the Columbia River Basin migrate to the ocean through a complex environment of tidal freshwater and estuarine (saline) habitats. However, our understanding of the spatio-temporal use of these habitats by different stocks of juvenile salmon is incomplete, which hampers the design of habitat restoration projects. Patterns of habitat use are stock- and size- specific, and management decisions prioritizing estuarine restoration activities must be based on established benefit to critical life history stages of threatened salmonid stocks.

The objective of this part of the research is twofold: First is to categorize the temporal and spatial variation of fish community structure using a landscape-scale monitoring program at characteristic shallow, nearshore environments. Time series of salmonid abundance and population size structure are emphasized. Second is to collect samples of juvenile salmon to investigate aspects of salmonid habitat use, including genetic analysis to determine stock-of-origin, chemical analysis of otoliths and scales to investigate estuarine residence and growth, and stomach analysis to evaluate trends in feeding. These latter analyses are detailed in sections below (Tasks 1.2 to 1.5). Together these components provide baseline time series of fish habitat use in an understudied region of the juvenile salmon migration corridor in the Columbia River.

Now in our fifth field season, we have conducted landscape-scale monitoring to characterize broad patterns of estuarine rearing and migration by juvenile salmon during the period, 2002-2006. Initially, we emphasized nearshore habitats of juvenile salmon in the lower Columbia River estuary below Puget Island. We established long-term indicator sites to compare abundance and size characteristics of juvenile salmon as they transit from tidal freshwater through oligohaline and euryhaline estuarine environments until they exit the river mouth into the plume. Results from these studies are summarized below. We also expanded investigation of salmon-habitat associations with semi-synoptic surveys (in conjunction with COE Channel Improvement funds) at sites that varied by different degrees of exposure to tidal and river currents (e.g., protected backwater areas versus exposed habitats along the main channel corridor). These data are described separately (Kagley et al. 2005). Beginning in 2006, we added eight additional sites in two tidal freshwater areas (Lord and Wallace Islands) of the mid-estuary. In 2007, we will continue the landscape-scale monitoring effort that spans this tidal freshwater to plume gradient, including sampling at the eight mid-estuary sites, and we will begin synthesizing and publishing our results.

Task 1.1. Select sites and conduct preliminary sampling.

In 2002, we established a beach-seine monitoring design to evaluate broad patterns of fish composition, abundance, habitat use, and rearing histories for various nearshore habitats where juvenile salmon enter and exit the lower estuary (Fig. 1). Herein we refer to this broad design as the landscape-scale or "estuarine-gradient" monitoring. Initially these stations were concentrated (1) in the area of Tenasillahe Island, where juvenile migrants must first choose whether to remain near the main estuary channel or select lower-energy backwater environments that lead into Cathlamet Bay; and (2) habitats near the estuary mouth, where salmon life-history diversity and relative abundances offer an overall indicator of estuarine and watershed conditions based on year-to-year variations among outmigrating juveniles. In 2003, we supplemented the estuarine gradient sampling with additional beach-seining sites chosen to represent a variety of other shallow water habitats and energy regimes within the upper estuarine transition zone of Cathlamet Bay and from an upper oligohaline area above Puget Island. Results from these supplemental sites, sampled during four periods in 2003-04, are summarized in Kagley et al. (2005). Beginning in 2006, we selected additional beach-seining sites to extend the tidal gradient encompassed by the landscape-scale monitoring to Rkm 101 in the mid estuary. These new sampling sites also allowed us to compare salmonid use along the peripheries of several islands with the results of finer-scale surveys of nearby wetland habitats described below in Objective 2.

<u>Progress to date:</u>

1. Seven monitoring sites in the lower Columbia River estuary were selected, and sampling by beach seine has been conducted monthly since November 2001.
2. Nine supplemental beach seine sites supported by other USACE funds were selected in 2003-04 and were sampled concurrently with the seven established estuarine gradient sites during May, July, and August 2004 (see Task 1.2 below). These additional sites expanded the variety of habitat types and locations depicted by our landscape-scale monitoring.
3. Eight new beach seining sites were selected further up-estuary during spring 2006, four each in the Wallace Island and Lord Island regions (Fig. 1). In both regions, we established a pair of beach seining sites adjacent to the navigation channel and a pair of sites along the islands' more protected backshore.

Proposed for FY 2007:

1. No additional site selection activities are scheduled for 2007.
2. We will continue landscape-scale monitoring activities in 2007, including sampling at the up-estuary sites at Wallace Island and Lord Island to characterize juvenile life histories and to assess whether estuarine-rearing source populations vary with distance from the river mouth.

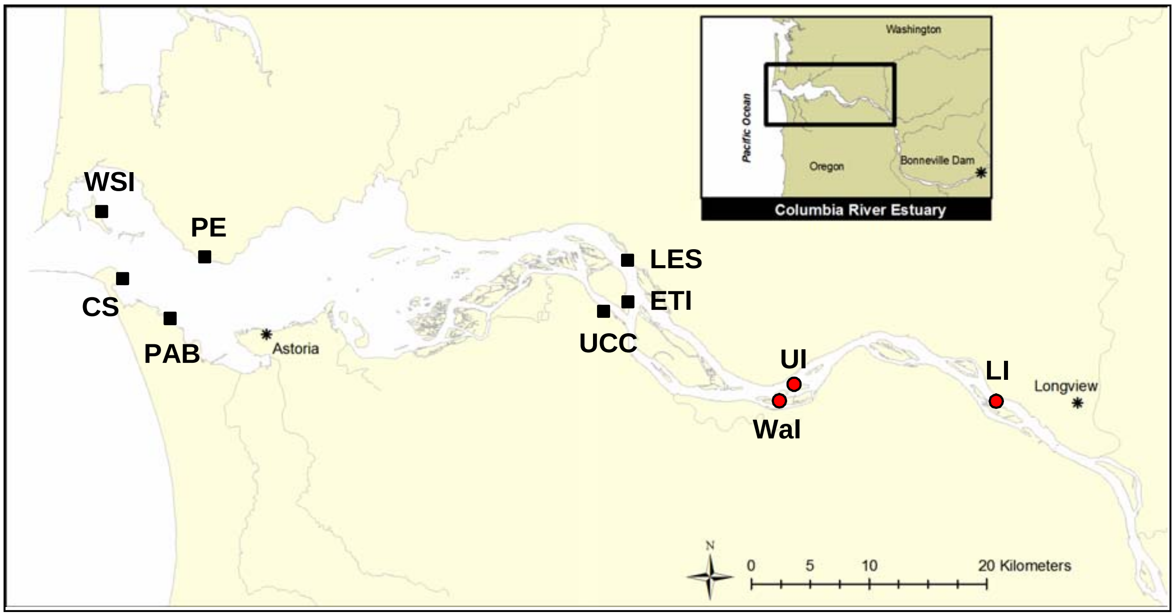

Figure 1. Landscape-scale beach seine sampling sites sampled monthly since 2002 (black squares): WSI, (West Sand Island), PE (Pt. Elice), CS (Clatsop Spit), PAB (Point Adams Beach), Lower Elochoman Slough (LES), East Tenasillahe Island (ETI), and Upper Clifton Channel (UCC). Sampling was discontinued at ETI in 2006 because fish collections yielded similar results to those at UCC and LES. In spring 2006 eight new beach seining sites were added in the vicinity of Wallace Island and Lord Island in the tidal fresh region of the estuary (red circles): a lower and upper island site (each) along the backshore of Wallace Island (WaI) and along the backshore of Lord Island (LI), and a lower and upper island site (each) along the foreshore (navigation-channel side) of LI and at the unnamed island (UI) just upstream of WaI. Catches at these sites are discussed with the results for upriver wetlands (Task 2.1).

Task 1.2. Monitor fish use at selected sites.

We are sampling fishes at selected survey sites to characterize habitat use and ecology, including species composition, relative abundance, size, and food resources. The sites are surveyed at monthly intervals. Fish are sampled with a 50-m variable mesh (19.0-, 12.7-, and 9.5-mm) beach seine with knotless web in the bunt to reduce descaling. During deployment, one end of the seine is anchored on the beach while the other is towed by a skiff to enclose a ~3500 m^2 semicircular area. We sort the catch on site. For non-salmonids, we measure (nearest 1.0 mm) and released a representative sample (30 individuals) of each species. All other non-salmonids are counted and released. For salmonids, we retain a maximum of thirty individuals for genetic, scale and otolith (see Tasks 1.4 and 2.3 below), and stomach (Task 1.5) samples. In addition, we measure up to seventy individuals of each salmonid species prior to release. All salmon are examined for fin clips, coded wire tags, and PIT tags. Long-term monitoring (5 to 10 years, with a minimum of 4 years) is planned to establish monthly, seasonal, and yearly variations for the various species of juvenile salmon that utilize these habitats.

<u>Progress to date:</u>

1. Ongoing beach seine sampling commenced in November 2001.
2. At the landscape scale, fish community structure exhibited consistent seasonal patterns during 2002-2005 based largely on salinity. Tidal freshwater sites numerically were dominated by sticklebacks during all seasons and years; while estuarine sites had a more diverse community structure.
3. We sampled >9600 Chinook, and caught similar numbers during 2002 through 2005. Chinook salmon ranked fourth in overall numerical abundance. Based on size frequency histograms, subyearling fish dominated the catch. Salmon were caught year-round, but CPUE tended to decrease with distance down river. Peak catches varied somewhat but were broadly distributed from February -July. In contrast, abundances of chum (*O. keta*) and coho (*Oncorhynchus kisutch*) salmon were restricted spatially and temporally. We sampled 1982 chum salmon, of which 97% were from estuarine stations. Chum salmon occurred from February until May when most individuals migrated to the ocean. We sampled a total of only 215 coho salmon at our landscape-scale monitoring sites.
4. Mean size of Chinook salmon generally increased with time, indicating growth during migration. The mean sizes of Chinook salmon collected at estuarine and tidal freshwater sites consistently differed, with upriver fish approximately 20-50 mm smaller than the corresponding estuarine fish for any particular survey date. While we likely sampled fish originating from different locations, this size difference suggests extended rearing in the lower Columbia system, rather than rapid migration down river.

Proposed for FY 2007:

1. We may scale back sampling at some lower estuary beach seine sites after December 2006 to accommodate sampling at the eight additional mid-estuary sites and to concentrate on data consolidation, analysis, and presentation. Decisions regarding such changes will be made at a project meeting in the fall 2006.
2. We will summarize 2002-2006 fish community structure data and integrate with a matrix of salmonid habitat use, size structure, genetic diversity, and physical parameters (see below) throughout the sample habitats.

Task 1.3. Characterize physical factors.

The physical variables that control and affect the availability of habitat in the lower river and estuary, such as flow velocity, salinity, and temperature, are being continuously monitored at a series of fixed stations. This project is benefiting from independently funded modeling (Baptista et al. 2005; Zhang et al. 2004; Zhang et al. In review) and monitoring activities of the CORIE observation and forecasting system (Baptista 2002; Baptista et al. 1998, 1999), which have a broader spatial scope, covering the full estuary and the near field of the plume. This task overlaps with and is detailed in Task 2.3 below.

We are also monitoring physical variables during beach seining surveys to allow direct comparisons between catch data and local hydrography. Before each beach seine set, we profiled the water column with a Sea Bird 19 plus CTD equipped with a Turner Designs SCUFA optical backscatter sensor and a Wet Labs Wet Star fluorometer. Four casts were made perpendicular to shore in a transect extending from the beach seine site (2-5 m depth) out to the channel 250-300 m from shore. Here we report general patterns of vertical and horizontal gradients of salinity and temperature.

Progress to date:

1. We have made over 1050 nearshore CTD casts to date, and detailed analysis is presently underway. Physical gradients measured at the landscape scale are both intense and variable. A strong seasonal component is associated with variation in river flow. In the lower estuary, vertical salinity gradients were remarkably strong, and salmon were

usually found in water of measurable salinity. At upper estuarine stations, conditions were seasonally variable and salinities had greatest variability. No salt was detected at the upriver sites. Within a site, water masses were nearly isothermal with both horizontal and vertical temperature gradients generally < 3^oC. However, seasonal temperature variation was large (6 to 22^oC) and, because we sampled near low tide, was mostly a function of river water temperature. Temperatures exceeded 20^oC during June or July through September each year. These temperature maxima are likely affecting salmon abundance and performance.

Proposed for FY 2007:

1. Complete analysis of remaining 2002-2006 data in relation to fish community structure and salmon habitat opportunity.

Task 1.4. Characterize juvenile salmon life history characteristics and habitat associations using scales and otoliths.

Reimers (1973) presented evidence that distinctive scale circuli of juvenile salmonids correspond to particular life-history patterns. We will use scale analysis to assess the diversity of possible life-history patterns represented in samples collected from specific habitats in the lower Columbia River system. Once validated, long-term scale collections could serve as a means to compare the performance of various life-history strategies based on their representation in juvenile and adult collections. We also will assess the use of scale circuli patterns to distinguish hatchery-reared fish from naturally spawned fish.

Otoliths are being collected from representative samples of salmonids and used to elucidate habitat use and growth. Chemical transects across sectioned otoliths will be conducted to track chemical changes in otolith composition. Since otoliths incorporate many chemical constituents in proportion to their environmental concentrations, the chemical transects can be used to reconstruct salmonid habitat use. In particular, analysis of age-specific strontium to calcium ratios have been related to migratory histories or environmental associations in several diadromous species (e.g. sockeye salmon, Rieman et al. 1994; striped bass, Secor and Piccoli 1996; eels, Tzeng and Tsai 1994; shad, Limburg 1995; and Arctic char, Radtke et al. 1996). Recent results from the Salmon River, Oregon and Skagit River, Washington showed that

Chinook salmon captured from estuarine marsh habitats exhibited a dramatic increase in otolith strontium at some point after emergence (Volk, unpub. data). Combined with data from water samples, it seems clear that this obvious chemical signal corresponded with migrations of the juvenile fish from freshwater to estuarine habitats. These data will be collected in addition to daily increment widths, which are used to assess relative growth rates.

Progress to date:

1. Draft of otolith and scale chemistry paper completed.
2. Approximately 200 otoliths were identified and removed from juvenile Chinook salmon from selected beach seine samples collected January through December, 2004. Fish were selected primarily from Point Adams boat launch and Lower Elochoman Slough to represent the saline and freshwater portions of the estuary, respectively.
3. Seventy-five specimens from the beach seine sampling have been prepared for LA-ICPMS (chemical) and daily growth increment analysis. The remaining 125 otoliths will be prepared by August 15, 2006.
4. Chemical analysis of 150 - 200 prepared otoliths will be completed in FY 2006.

Proposed for FY 2007:

1. From fish samples collected with the beach seine, continue tracking strontium and other chemical elements of otoliths to determine juvenile salmon life history traits, including size at estuary entrance and estuarine residence time. Analytical priorities will include fish sampled from selected lower estuary sites (saline portion of estuary) and upper estuary sites (freshwater portion of the estuary) in 2005. Priority sites, priority dates, and fish chosen for analysis will be coordinated with other researchers on our study team to allow comparison of biological data (e.g., genetics, life history, food consumption, etc.) among individual fish.
2. Continue measurement of daily growth increments for a sub-sample of 2004 otoliths to calculate growth rates and residency.
3. Compare growth patterns on scales of known hatchery (marked) and unmarked Chinook salmon.

4. Compare historic growth and life history patterns of juvenile Chinook salmon based on scale measurements reported by Rich (1920) with results from scales recently collected in the Columbia River Estuary. Scale measurements will include distance to each apparent estuary check, spacing of scale circuli, and distance to the scale edge.
5. Synthesize and publish results of historical and contemporary life history and growth comparisons from juvenile Chinook salmon scales.

Task 1.5. Monitor trophic relationships of salmonid species and life history types in selected habitats throughout the lower Columbia River and estuary.

We will examine spatial and temporal variation in juvenile salmonid diet associated with marine, mixing, and tidal freshwater sites to assess life-history specific associations with estuarine habitat. An assessment of salmonid stomach contents will allow us to establish a sensitive and practical long-term sampling design for both salmon and estuarine prey resources. Data processing will include (1) the percentage of empty stomachs, (2) the weight of stomach contents, and (3) diet composition by number and biomass (e.g. terrestrial insects, benthic invertebrates, plankton, fish). These data will be used to determine the extent to which salmon feed in the estuary, the prey types consumed, and the nature of seasonal or spatial variation of salmon diets.

Progress to date:

1. Fish collected from the beach seine monitoring sites (Task 1.2) were stored at -80°C until the stomachs were dissected and preserved in 10% buffered formalin. After completion of diet analysis, all stomach contents were placed in 70% ethanol for long-term archival storage. Diet data were entered into a database containing all diet records from this project. As of 29 November 2005, a total of 3,849 juvenile chinook stomachs had been removed, preserved, and cataloged in the project's master database. An additional 700 stomachs (approximately) have been saved and need to be cataloged. This data set encompasses the period December 2001 to the present.
2. Since 28 April 2005 a fisheries student intern from Clatsop Community College has assisted with stomach processing, data entry, and sample management.

3. In January of 2006, we constructed an electronic database to store all diet data. Data tables from this database can be directly linked to the master database by individual fish identification numbers.
4. As of 11 July 2006, 733 chinook stomachs representing fish from all seven estuary sites have been fully analyzed for diet and stomach parasite composition (Level 2 stomach processing; see Tables 1 and 2 for the sample distribution among stations, months and years). An additional 139 stomachs from an entirely freshwater site (LES) and an estuarine site (PAB) have been analyzed for seasonal changes in stomach fullness, stomach weight, and parasite composition (Level 1 stomach processing).

Table 1. Distribution of samples by station and month, for Level II processing. Note that no fish were saved during November or December due to low catch numbers.

STATION and HABITAT TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	TOTALS
WSI - Marine					29		19				48
CS - Marine					32	9	19				60
PAB - Mixing	4	21	10	14	65	11	35	10	9	9	188
PE - Mixing			1		28		23				52
ETI - Tidal freshwater					37		15				52
UCC - Tidal freshwater					41		30				71
LES - Tidal freshwater	14	24	20	32	47	22	51	18	13	21	262
TOTALS	18	45	31	46	279	42	192	28	22	30	733

Table 2. Distribution of samples by station and year, for Level II processing.

STATION and HABITAT TYPE	**2002**	**2003**	**2004**	**2005**	**TOTALS**
CS - Marine	22	28	10		60
WSI - Marine	20	18	10		48
PAB - Mixing	21	95	33	39	188
PE - Mixing	21	21	9	1	52
ETI - Tidal freshwater	17	28	7		52
UCC - Tidal freshwater	19	43	9		71
LES - tidal freshwater	89	99	50	24	262
TOTALS	209	332	128	64	733

5. Diet analyses indicate that most subyearling chinook feed actively in the estuary. Average stomach fullness, by volume, was 85%. Fifty-seven percent of stomachs examined were 100% full by volume. Less than 2% of stomachs were effectively empty (i.e. < 10% full by volume).

6. Benthic estuarine amphipods (*Corophium salmonis* and *C. spinicorne*) and terrestrial flies (Diptera) were the dominant prey types in the diet, as indicated by the Index of Relative Importance (IRI)[1]. For example, these two prey categories alone contributed on average 79% to the total IRI of all prey items from January to October within a single site. Other prey types accounting for the rest of the diet included crab megalopae, terrestrial insects and spiders, polychaete worms, gammarid amphipods, mysids, and cladocerans, as well other invertebrates.
7. Benthic amphipods (*Corophium salmonis* and *C. spinicorne*) and terrestrial flies (Diptera) consistently dominated the diet, contributing over 70% to the total IRI of each site in each habitat type (marine, mixing, or tidal freshwater). Site-specific differences in diet appear in both the dominant and non-dominant diet components. For example, *Corophium spinicorne* is more important in the diets of fish captured in mixing and marine habitats, whereas *Corophium salmonis* is more important in tidal freshwater habitats. The types of non-dominant prey found in the diet often correspond to the habitat in which the fish was captured. For example, marine cumaceans (a type of benthic crustacean) are only found in the diets of fish captured in marine habitats.
8. During the analysis of 2004 and 2005 samples, our student intern discovered the exotic New Zealand mudsnail, *lksdfjad*, in two chinook stomachs. To our knowledge, this is the first report of this snail in Chinook diet from fish caught outside of a hatchery environment, and is the first evidence of native salmon directly interacting with this introduced snail in the Columbia River estuary.
9. Given the diversity of diet items seen so far, a comprehensive monitoring of prey resources would need to include the benthos, terrestrial insects, plankton, and nekton (including exotic species like the New Zealand mudsnail).
10. The dietary dominance of *Corophium* amphipods and dipteran flies implies that two different habitats are especially important to the food supply of subyearling Chinook in the lower Columbia River: benthic habitats supporting *Corophium* populations (e.g. fine sands/muds experiencing salinities between 0 and 25 ppt) and wetland habitats supporting terrestrial flies (e.g. tidal marshes).

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[1] The Index of Relative importance (IRI) is a statistic that accounts for the relative contribution of a prey item to the diet, taking into consideration both the number and mass of each prey type consumed.

11. Terrestrial insects produced in wetland habitats appeared in the diets of fish that were not captured within wetland habitats. This indicates that wetlands export insect production to non-wetland habitats or serve as feeding grounds for fish that spend part of their time away from wetlands.

Proposed for FY 2007:

1. Continue collecting monthly diet samples at beach seine sites.
2. Continue processing stomach samples, including 2005 and 2006 collections and the new upriver sites at Wallace and Lord Islands.
3. Generate a peer-reviewed publication on Chinook salmon diet composition, synthesizing results of monthly time series and between-station comparisons.
4. Generate a short publication on the interaction between Chinook salmon and the New Zealand mudsnail in the lower Columbia estuary.
5. Continue involvement of student intern to assist with sample analyses and publications.

Objective 2. Describe salmonid use and performance in selected emergent and forested wetlands and their relationship to local habitat features.

Habitats that are important for rearing ocean-type juvenile salmon in other Pacific Coast estuaries have not been systematically sampled in the Columbia (Bottom et al. 2005). Shallow water wetlands, including both emergent marshes and scrub-shrub or forested wetlands have received little attention, even in the comprehensive CREDDP studies in the 1980s (Bottom et al. 1990). Our research approach requires that we accurately establish relevant empirical associations between habitat variables (both physical and biological) and juvenile salmon. If we develop empirical associations between habitat attributes (e.g., salinity, depth, channel morphology, vegetation type, prey resources, etc.) and salmon distribution and performance (e.g., presence, abundance, residence time, and growth) for various wetland types, then we can predict responses of juvenile salmon to past or future physical change. This information is needed to establish criteria for restoring estuarine habitats.

Understanding of salmon-habitat associations must also account for the dynamics of wetland succession and disturbance that, over periods of decades or longer, shift the landscape of salmonid habitat opportunity across the entire estuary. Wetland habitats in the Columbia River estuary exhibit a natural sequence of developmental stages suggestive of vegetative and geomorphic succession, including low emergent marshes with complex dendritic channels; scrub-shrub wetlands of intermediate elevation and complexity; and mature forested wetlands, consisting of deep slough systems littered with large quantities of woody debris. The ecological functions of wetlands of various successional stages (including their use by salmon) may depend on their geographic position along the tidal gradient. Our surveys of wetland habitats are intended to contrast fish, prey resources, and habitat conditions among examples of the successional states of vegetative and geomorphic types represented in the Columbia River estuary. We then will use GIS to infer changes in wetland rearing opportunities for salmon over the past century by comparing the historical and contemporary geography of wetland habitats in various successional stages (see Task 3.3).

Since 2002 we have sampled a series of emergent, shrub, and forested marshes to characterize salmonid use and performance among different wetland types and to compare effects of geomorphic and vegetative structure and position on habitat functions for salmon (Table 3, Fig. 2). Throughout this research period, we have sampled a pair of Russian Island channels to monitor trends in salmon habitat use and prey availability in a lower estuary emergent wetland. All other wetland sites have been sampled for a maximum of 2 or 3 years and have been replaced thereafter with additional sites further upriver to expand the variety of tidal wetland types, geographic locations, and Chinook salmon life histories characterized by our surveys. Fish and prey resource sampling initiated at Wallace Island (RKm 77) and at Lord Island (RKm 101) sites in 2006 will be continued in 2007.

We also estimated salmon residence times, growth, and consumption rates at the Russian Island emergent marsh in 2005 and 2006. We will explore whether similar studies are feasible at Wallace or Lord Island wetland sites in 2007. We will continue to use prey resource, consumption, and temperature data to compare salmon growth potential among diverse wetland types using a bioenergetic model.

In 2006, we established a pair of beach seining sites along the backshore of Wallace Island (WaI) and Lord Island (LI) and another pair of sites along the foreshore of each island. These sites (1) increase the up-estuary extent of our estuarine gradient sampling, as described in Objective 1; and (2) allow comparisons of salmonid life histories and use of peripheral island habitats with results of our finer-scale surveys of the interior wetland channels of each island.

Table 3. Trapnet locations and year of sampling at each wetland site.

Station – marsh type	**RKm**	**2002**	**2003**	**2004**	**2005**	**2006**	***2007* (*proposed*)**
Russian Island (RI) – emergent	35	x	x	x	x	x	x
Seal Island (SI)– emergent	37	x	x	x			
Karlson Island (KI)– forested	42	x	x				
Karlson Island (KI)– shrub	42	x	x	x			
Welch Island (WeI) – shrub	53			x	x		
Wallace Island (WaI)– emergent/scrub-shrub/ forested	77					x	x
Lord Island (LI)– emergent/scrub-shrub/forested	101					x	x

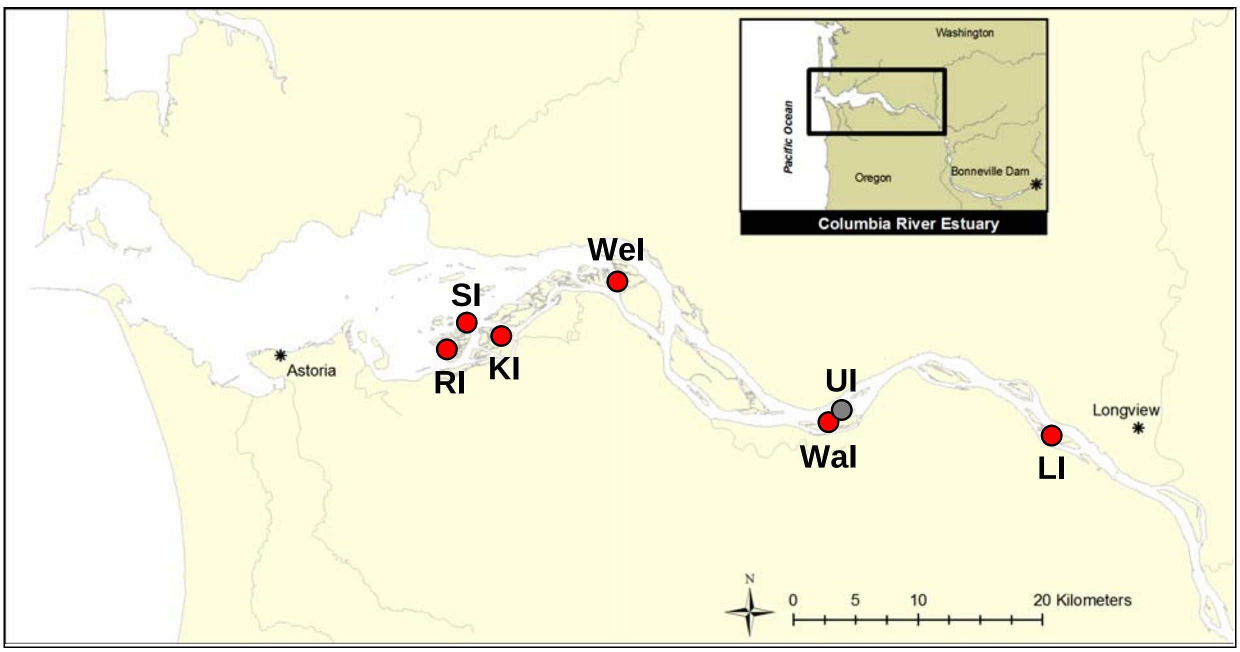

Figure 2. Location of all wetland sampling stations (red dots) described in Table 3. A pair of replicate wetland channel sites was sampled at each station. In 2007 we will continue sampling interior wetland sites at Russian (RI), Wallace (WaI), and Lord (LI) islands. For direct comparison with wetland samples we also will continue beach seining along the backshore of Lord Island and Wallace Island, and along the foreshore of Lord Island and an unnamed island (UI) just upstream of Wallace Island.

Task 2.1. Sample fish at selected emergent and forested wetland sites from Cathlamet Bay to the Lord Island region

At the outset, this study focused shallow-habitat sampling in the Cathlamet Bay region (Fig. 2, Table 3) of the lower estuary, which contains the largest concentration of shallow wetlands and spans the full oligohaline-brackish estuarine gradient available to Columbia River salmon. We extended the sampling area upriver in 2004-05 to include shrub wetlands in the tidal fresh zone at Welch Island (near RKm 53). In 2006, we expanded our wetland studies further upriver to Wallace (Rkm 77) Island and Lord (Rkm 101) Island, where tidal ranges are less, and vegetation grades from emergent grasses at the channel mouths to a mixture of shrubs and trees along the upper channel network. To characterize fish composition and relative abundance, we used beach seines along the outer island margins and pole or bag seines and blocknets within the shallow tidal channels draining the interior of each island. We will repeat this sampling design in 2007.

Progress to date:

1. We continued monthly monitoring of selected channel sites at the Russian Island emergent marsh (Fig. 2), March through July, 2006. For all sample dates and trapnet stations, we retained a subsample of salmonid species for dietary, genetic, and life-history analyses.
2. As in previous years, the 2006 trapnet results showed consistent use of the Russian Island emergent marsh by subyearling Chinook salmon; however, numbers were substantially lower than in prior years (See Table 4). Chum salmon abundances were very low in 2006 and limited to a few individuals in April.
3. In February 2006 we tested the feasibility of using trap nets to sample forested/scrub-shrub wetlands at Wallace Island. Because tidal exchange was not sufficient to fully dewater larger channels, and river levels were largely determined by mainstem dam discharges, we concluded that other techniques are necessary to sample wetland habitats above RKm 53.

Table 4. Total numbers of Chinook salmon captured by month and year, at the Russian Island trapnet site, North and South channels combined.

	2002	2003	2004	2005	2006
March	6	22	3	17	6
April	30	147	38	36	13
May	94	199	39	39	5
June	36	6	7	18	1
July	88	4	17	40	11
August	13	0	1	1	
Total w/ August	267	378	105	151	*36

* The 2006 total is for March through July only.

4. We used block nets and pole or bag seines in 2006 to monitor fish use of interior channels of upper river wetlands at Wallace and Lord Islands. Biological samples were collected at each site for genetic, life history, and stomach analyses.
5. Highly variable spill at Bonneville (e.g., 2.4 kcfs in March vs. 150 kcfs in April) and changing water levels among the channel sites required frequent adjustment of the sampling protocol. Differences in channel size between the two sampling sites at Wallace and at Lord Island also required different sampling methods. For these reasons, total catches at Wallace and Lord Island in 2006 were not comparable among channel sites or even among all survey dates within each channel site. In 2007 we will standardize the sampling protocol as much as possible to better compare sampling sites and time periods.
6. We also sampled with beach seines two sites (upper and lower) along the foreshore (i.e., navigation-channel side) and two sites (upper and lower) along the backshore (southern side) of Wallace and Lord Island (see Objective 1). The beach seine samples will be used to compare juvenile life histories and source populations of salmon along the peripheral shores and within the shallow interior wetlands of each island.
7. Chinook salmon dominated the catch of salmonid species, comprising approximately 98% of the May – July total at peripheral and interior Wallace and Lord Island sites. At peripheral island sites, Chinook catch per seine haul peaked in May (although we have no data for backshore sites in April because of high water) (Table 5). Small subyearling Chinook salmon were present at all survey sites throughout the spring and summer

period. Chinook salmon ranged from 31-75 mm FL in March to 41-105 mm FL in July. Chum salmon also were present in March and April at most sites. Coho salmon were captured at peripheral beach seine sites during April and May.

Table 5. Counts of juvenile Chinook salmon at two beach seining sites each on the mainstem (north shore) and back shore of Wallace and Lord Islands, March – July 2006.

Location	**Beach Seine**		**March**	**April**	**May**	**June**	**July**
Unnamed island	foreshore	upper	5	5	21	88	110
		lower	9	1	50	61	61
Wallace Island	backshore	upper	10*	**	81	30	3
		lower	4*	**	67	54	0
Lord Island	foreshore	upper	17	64	177	79	151
		lower	50	22	130	78	99
	backshore	upper	21*	**	85	66	30
		lower	50*	**	219	31	35

* sampled with 40m bag seine this month and switched to 50m beach seine in May
** impossible to seine due to high water

8. We collected tissue samples to genotype a subset of Chinook salmon collected at each wetland site and at the two Russian Island sites selected for salmon residency studies (described below). We have completed genetic comparisons from all trapnet and beach seine sites for selected survey dates in 2002 and 2003. The results indicate that most Chinook salmon from backwater and shallow near-shore habitats are ocean-type juveniles from the lower Columbia River Evolutionarily Significant Unit (ESU). However, fish sampled in deep channel habitats with a purse seine reveal a larger proportion of Interior Columbia River stocks compared with those collected in shallow and off-channel areas. Although low in abundance, individuals from all other Columbia River ESUs nonetheless occur in wetland habitats. In 2005 we expanded the genetic baseline to allow further segregation of the various sources of Lower Columbia River Chinook salmon. However, loss of other funds that supported the genetics research prevented any additional analyses of genetic samples in 2006.
9. In 2006, we refined the experimental design and repeated the previous year's salmon residency study in two areas of a large distributary channel of Russian Island (Fig. 3).

We extended the marking period from four to eight days and continued recapturing fish well beyond the last day of marking. The 2005 study used a batch marking technique to identify fish for residency estimates. We used the same marking methods in 2006, except all fish that were sufficiently large to accept PIT tags ($\geq$ 55 mm) were individually marked.

We marked 918 Chinook over eight days (Apr 3-7 and Apr 9-11). Of those, 574 were PIT tagged, and 344 were batch marked. During the recapture period (Apr 4-May 25) we collected a total of 224 (24.4 % recovery) tagged or marked Chinook, including 147 (25.6 % recovery) that were PIT tagged and 77 (22.4% recovery) that were batch marked. The trend in residency pattern in 2006 was similar to the pattern observed in 2005, where many fish left the island within the first several days, and others remained for extended periods. The overall residence time was slightly greater in 2006 than in 2005. For example, half of the salmon marked in 2005 left Russian Island after 3 days, average residence time was 5 days, and maximum residency extended for 17 days. In contrast, half of the marked salmon left after 5 days in 2006, estimated average residence time was greater (7 days), and maximum residency extended for 34 days. A greater proportion of fish reared for longer periods in 2006 than in the previous year: 32 Chinook (14% of recovered marks) were recaptured more than 2 weeks after marking, and 14 Chinook (5% of recovered marks) were collected more than 3 weeks after marking.

The increase in observed residence time, in part, may reflect the refined experimental design, expanded sampling effort, and improved mark/recapture techniques. Even though the total number of juvenile Chinook marked in 2006 was 40% less than the number marked in 2005 (918 vs. 1508), the 2006 recapture rate was several times greater than that of the previous year (24.4% vs. 7.8%). In both years, however, the residency measurements must be considered minimal estimates: we only sampled a small portion of the Russian Island marsh-channel network, and therefore, do not know whether some individuals remained for extended periods elsewhere within the island complex; we cannot account for losses (i.e. mortality) unrelated to migration from the study area; and individuals could have returned intermittently to the study area long after we suspended sampling to recapture marked fish.

Figure 3. Two sampling areas for mark-recapture studies at Russian Island in 2005 and 2006. The 2006 study used a combination of acrylic paint and PIT tags to mark salmon and determine residency periods for individuals recaptured in the two locations. The 2006 study period extended from April 3 to May 25.

Recaptures of individually tagged fish during the 2006 study yield some of the first quantitative estimates of estuarine growth for Columbia River Chinook salmon. Growth rates averaged 0.5 mm FL/d and ranged from 0 to 1.5 mm/d. These results are consistent with independent estimates for estuarine-rearing Chinook salmon derived from our ongoing otolith and scale analyses (Eric Volk and Lance Campbell, unpublished data) and with growth estimates reported for salmon in other Pacific Coast estuaries.

Proposed for FY 2007

1. We will continue to collect one or more trapnet samples at Russian Island during the peak salmon abundance period to maintain continuity of prey resource and fish data (i.e., salmon abundance, life history, genetics, and stomach contents).
2. We will continue to compare salmonid use and prey resources in emergent and scrub-shrub/forested wetlands at Wallace Island and Lord Island. Monthly sampling with block nets and seines will continue in each habitat type from March through July or August, when salmon vacate backwater areas. Occasional sampling may be required later to assess potential fall or winter use of upriver wetlands. We will retain a subsample of all salmonid species from each site and date for dietary, genetic, and life history analyses.
3. To allow comparison of salmon abundances despite the changing water levels at Wallace and Lord Island, we will attempt to standardize the wetland sampling protocol as follows:
   (a) Collect monthly samples with the bag seine at one or two standard index sites within the larger (i.e., lower) of the two interior channels at each island station. These samples will be used to track trends in relative abundance and to retain samples for various biological analyses (i.e., genetics, life history, stomach contents). However, we may be unable to collect relative abundance data during later summer months (July, August) when water levels drop to low levels and lower island sites are no longer accessible by boat. In these months we will attempt to collect a sample of fish for biological analyses (only) using smaller pole seines.
   (b) Deploy block nets monthly near the mouths of the smaller of the two interior channels at each island and establish a standard mark-recapture design for estimating absolute salmon abundance each survey month and for collecting biological samples. Quantitative population estimates for each small channel will allow salmon densities at Wallace Island and Lord Island to be compared with estimated densities at other wetland sites.
4. We will explore the feasibility of implementing a salmon residency/movement rate study (and associated consumption rate study; see Task 2.2) at Wallace or Lord Island to compare with the 2005-06 Russian Island results. However, the manpower required to recapture marked salmon over extended time periods will make it difficult to complete

these studies without eliminating other estuarine monitoring activities. One possible solution would be to deploy a remote PIT detector at Wallace or Lord Island, which would reduce manpower requirements for salmon recaptures. However, because sampling scales (i.e., larger Russian Island habitat complex vs. simple marsh and channel network at Wallace and Lord Islands) and efficiencies (i.e., discrete recapture with nets at Russian Island vs. continuous remote detection of PIT tags at Wallace or Lord Islands) will differ, it may be difficult to directly compare residency results between sites. We will discuss these options and develop a final sampling plan at our annual project meeting in February 2007.

5. In 2007, we will prepare a draft manuscript for peer-reviewed publication summarizing fish composition and habitat-use patterns in Columbia River wetlands.
6. With funds provided by this proposal, we will resume genetic analyses. These will include beach seine and trapnet samples collected after 2003, continuing the priorities for spatial and temporal comparisons that we developed for the 2002-03 samples. We will also analyze genetic samples collected at Wallace and Lord Island in 2006 to examine whether the source populations using these upriver sites differ from those observed in the lower estuary.

Task 2.2. Monitor availability of invertebrate prey resources and food habits of juvenile salmonids and other selected fish predators.

To assess the potential benefits of individuals occupying shallow wetland habitats, we are simultaneously monitoring relative availability of invertebrate prey (“fallout” insects, benthic macroinvertebrates) and the diet composition of juvenile salmon captured in emergent and forested/scrub-shrub wetlands. Correspondence (overlap) between the diets of salmon and available prey will allow us to examine trophic linkages between shallow-water habitats and juvenile salmon. Our existing dataset suggests that insect fall-out traps and, to a lesser degree, benthic cores adequately characterize prey resources selected by subyearling, ocean-type juvenile Chinook salmon. However, if we find that zooplankton are a significant component of salmonid diets at the mid estuary sites, we will expand the prey resource sampling to include planktonic invertebrates.

Progress to date:

1. In 2006, we retained for dietary analysis a subsample of up to 10 individuals of each salmonid species found at each site for each survey date. We froze whole fish for subsequent stomach analysis because specimens also are required for corresponding life history (otolith) and parasitological examination. Moreover, because most fish in wetland samples were relatively small, we concluded that gastric lavage may not provide a suitable alternative to freezing whole fish for stomach samples. Before processing, the stomachs were removed from the frozen fish and placed in a buffered 10% formalin solution.
2. To assess the relative availability of prey organisms and their importance to salmonid diet and growth, we collected benthic organisms and fall-out insects at each wetland site coincident with fish sampling. We collected benthic organisms in marsh and slough channels with a sediment core and insects on the marsh surface with fall-out traps using methods described by Gray et al. (2002). All prey samples were preserved for later analysis. Benthic invertebrates were preserved in a buffered 10% formalin solution, and the insects were preserved in 70% isopropanol.
3. Juvenile Chinook and prey resource samples from 2004 have been processed, and analysis of the 2005 samples is ongoing. These data will continue the time series for the Cathlamet (Russian Island) emergent marsh index site and will support comparative analyses for the Welch Island scrub-shrub/forested wetlands, the Karlson Island forested and scrub-shrub wetlands, and the mixed emergent and scrub-shrub/forested wetlands at Wallace and Lords islands.
4. We have initiated two new M.S. thesis research projects by University of Washington graduate students, with significant funding (for graduate student Research Assistantship support and tuition) provided by the School of Aquatic and Fisheries Sciences. Based on M.A. Lott's (2004) thesis results documenting the contribution of emerging chironomid insects to juvenile Chinook salmon in lower estuary wetlands, Mary Ramirez is assessing variation in the emergence dynamics of chironomids at Russian Island. Another graduate student, Sarah Pilseth, is basing her thesis research on the tremendous abundance of threespine stickleback, *Gasterosteus aculeatus,* and their overlapping distribution with

juvenile Chinook salmon in emergent marshes. She is conducting detailed studies of potential feeding and behavioral interactions between stickleback and juvenile Chinook at our Russian Island site, as well as other CREST study sites in the Chinook River, Grays River, and Youngs Bay. Both students began sampling early in 2006 and are scheduled to complete their thesis research in late winter 2007 or spring, 2008.

5. Based on Mary Austill Lott's M.S. thesis (Dec. 2004; University of Washington, School of Aquatic and Fishery Sciences), we will soon submit a draft manuscript to the journal *Estuarine and Coastal Shelf Science*, entitled "Habitat-Specific Feeding Ecology of Ocean-Type Juvenile Chinook Salmon in the Lower Columbia River Estuary."

Proposed for FY 2007:

1. We will process samples of subyearling Chinook salmon and prey organisms (benthic invertebrates and fall-out insects) from wetland sites sampled in 2005 and 2006. Priority samples for analyzing prey composition and salmon feeding selectivity will be chosen (1) to allow comparison of prior results from scrub-shrub and forested wetlands at Karlson and Welch islands with results for emergent marsh and scrub-shrub/forested wetlands at Wallace and Lord islands further up-estuary; (2) to depict interannual variability at the Russian Island emergent marsh site, and (3) to provide corroborative samples for Sarah Spilseth's M.S. thesis research evaluating interactions between threespine stickleback and juvenile Chinook salmon.
2. In 2007, we will continue to collect juvenile Chinook salmon and threespine stickleback stomachs and invertebrate prey during monthly fish surveys (March – August) at emergent/forested/scrub-shrub sites at Wallace and Lord islands. In addition, we will continue limited sampling at the Russian Island emergent-marsh site during peak salmonid densities in the spring (to evaluate interannual variability). Invertebrate prey will be sampled at all sites using previously established methods (insect fall-out traps, benthic cores) and the following new methods if justified: (1) vertical zooplankton hauls from near-bottom to the surface with a 0.333-mm mesh 0.5m ring net to capture water column zooplankton (if they appear as a prominent diet component); and (2) insect emergence commensurate with M. Ramirez M.S. thesis research.

3. If salmon residency studies (described above) prove feasible, we also will conduct a concurrent 30-hr daily ration (food consumption) experiment at Wallace or Lord Island in 2007.

Task 2.3. Characterize physical factors

We are monitoring the physical attributes within selected estuarine and oligohaline habitats, including temperature, salinity, tide level, and other features. The characterization and interpretation of physical factors includes: (1) monitoring the physical attributes in Cathlamet Bay, (2) monitoring the physical attributes of beach seine sites and of channels located within selected marsh habitats, (3) estimation of physically-based habitat opportunity indicators, and (4) use of modeling as a monitoring tool (2003 and beyond). Each of these subtasks is discussed below.

Subtask 2.3.a. Monitor physical attributes in the estuary

A sub-network of the real-time CORIE field stations (Fig. 4) was installed and has been collecting continuous measurements of water level (WL), salinity (S), and temperature (T) from sensors installed at one level in the water column. These stations and their base sensors are maintained in a long-term basis.

Marsh Island has been instrumented with atmospheric sensors for direct measurement or estimation of air temperature, relative humidity, barometric pressure, wind (speed, direction and gust), solar radiation, long-wave radiation, latent heat and sensible heat. Observations of atmospheric parameters will be maintained continuously during the course of the estuary studies. Additional observations (multi-level observations of temperature and one-level observations of turbidity) at Marsh Island were explored in 2005, but not considered logistically feasible at the present level of effort.

We delayed to FY07 the deployment of a new CORIE station at Wallace Island. Due to considerations of availability of instrumentation, this delay will allow us to install the new station without sacrificing the Tenasillahe Island station.

The CORIE web site reports the data above (except some of the atmospheric parameters), both in real-time (e.g., http://www.ccalmr.ogi.edu/CORIE/network/tnslh/) and in archival form (e.g., see http://www.ccalmr.ogi.edu/CORIE/data/publicarch/tnslh/index.html).

Progress to date:

1. A large sub-network of sensors has been maintained to facilitate habitat characterization in the Cathlamet Bay region. Observations of conductivity/salinity, temperature, and pressure/water level have been conducted regularly at the following stations[1]: Mott Basin (where atmospheric parameters are also measured), CBNC3 (supported through a separate project), Elliot Point, Marsh Island, Svensen Island, Woody Island (now supported through this project), Tenasillahe Island and Grays Point (supported through a separate project). An atmospheric station is also maintained at Marsh Island.

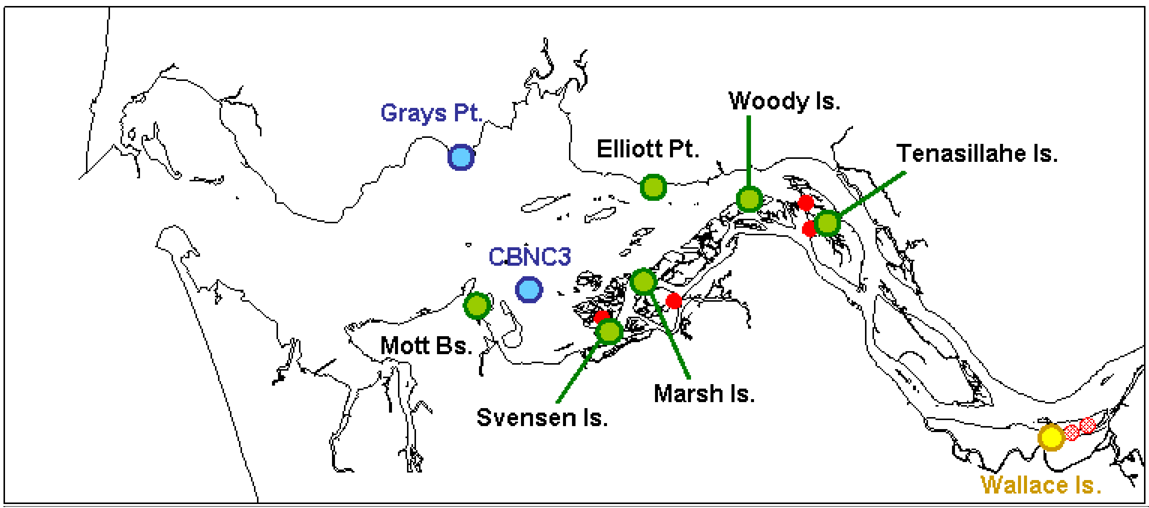

Figure 4. Six CORIE stations were maintained in FY2006 as a part of this project (green circles). Initially planned for FY2006, we are proposing to install in FY2007 an additional station at Wallace Island (yellow circle). The two other CORIE stations (blue circles) shown in the map are supported through a different Corps of Engineers project (channel deepening monitoring). Red circles represent trapnet sites for spatial reference.

2. Web-based display of unverified data is routinely conducted in real time, with revised formats introduced in July 2004 (including selected atmospheric parameters). Verified archival data are available through June 2006 as illustrated for temperature in Figure 5.
3. Statistical characterization of temperatures (Fig. 6) and salinities has been conducted for all stations. Correlations between Cathlamet Bay temperatures and temperatures at Bonneville Dam and Beaver Army Terminal were investigated, establishing that median temperatures in Cathlamet Bay are driven from upstream temperatures.

[1] Not all stations measure all variables (see http://www.ccalmr.ogi.edu/CORIE for details).

Proposed for FY 2007:

1. Maintain physical water monitoring at five stations: conductivity/salinity, temperature, and pressure at Elliot Point, Marsh Island and Svensen Island; salinity and temperature at Mott Basin; and temperature and pressure at Woody Island. Stations CBNC3 and Grays Point will continue to be maintained through separate funding.
2. Install a new CORIE station (temperature and pressure sensors) at Wallace Island, to support new beach seine and trapnet stations to be added in this region.
3. Maintain monitoring of atmospheric parameters at Marsh Island, and improve associated data verification procedures.
4. Continue quality control of the data and access on the web.

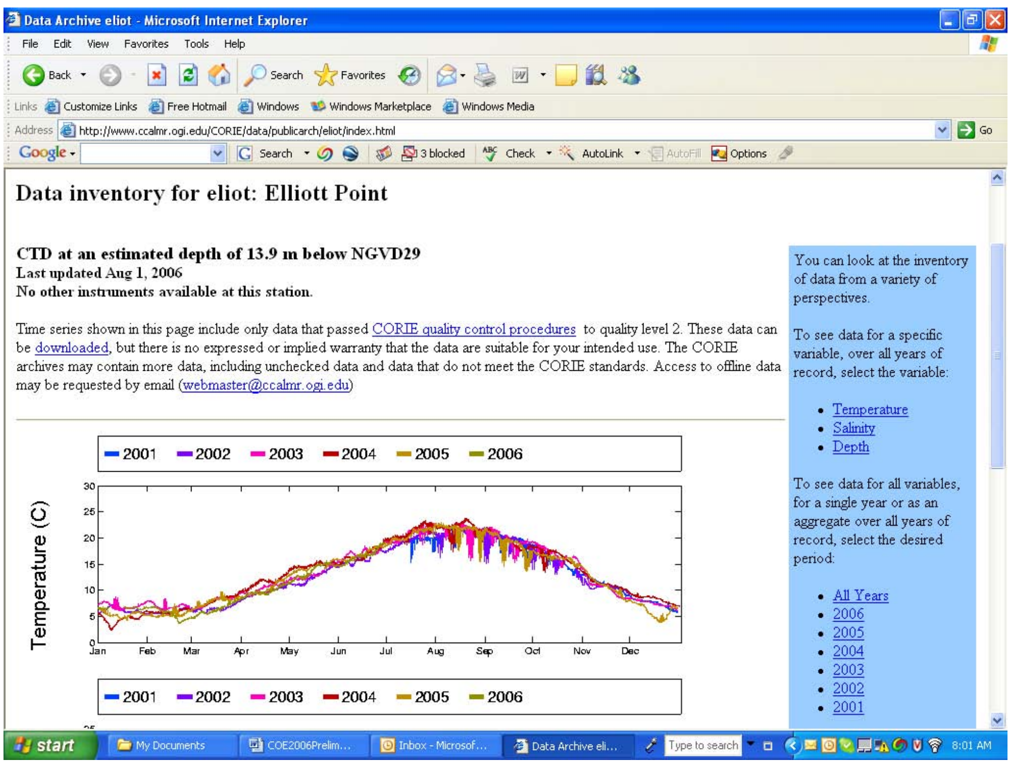

Figure 5. Web display of Elliot Pt. temperatures.

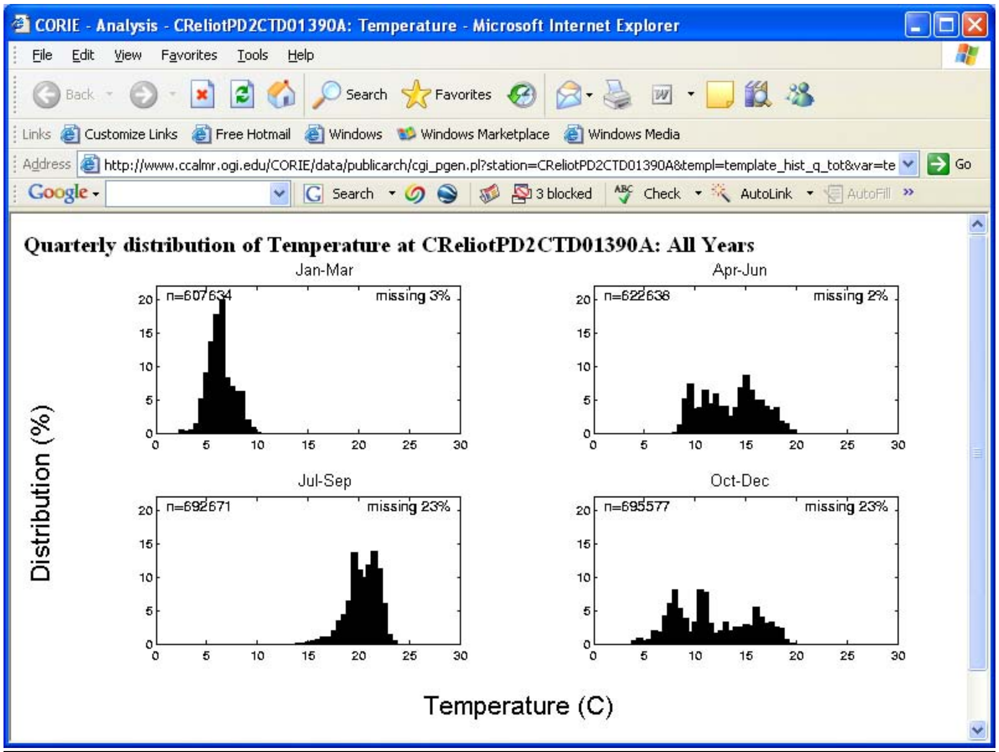

Figure 6. Seasonal statistics for Elliot Pt. temperature.

Subtask 2.3.b: Monitor physical attributes within selected marsh habitats.

In each region of emergent marsh and scrub-shrub/forested wetland sampling, and in some cases individual channels/sloughs, we will continuously monitor physical conditions that are potentially important determinants of juvenile salmon access and performance in local habitats. The continuous monitoring will be maintained as long as the field sampling program is repeated.

<u>Progress to date:</u>

1. We continuously monitored water temperatures with data loggers located at several locations along the channel networks of one of the replicate emergent channels at Russian Island and at one channel each at Wallace and Lord Islands.
2. We deployed pressure gauges at the Russian Island, Karlson Island, and Welch Island sites in July 2004 to continuously monitor water levels at each trapnet site. In 2005, we continued monitoring tide levels with the pressure gauge at Russian Island and Welch Island. The Russian Island pressure gauge (only) was maintained through the 2006 sampling season.

Proposed for FY 2007:

1. We will continue monitoring temperature and water levels at Russian Island and deploy temperature and pressure gauges in the vicinity of new wetland sampling sites to be chosen at Wallace and Lord islands.
2. We will collect spot and (channel) profile elevation data for Wallace and Lord islands using methods similar to the 2004 high-resolution GPS surveys for marsh and channel elevations conducted at Russian Island, Welch Island, and the Karlson Island scrub-shrub channel. These results will provide information to assess habitat opportunity for salmon under various tidal and river flow conditions (see Subtask 2.3.d), and will aid interpretations of vegetative composition (see Task 2.4) and the successional stage of each wetland site.
3. Although it has yet to be released, we are hopeful that LiDAR coverage from November 2004 will become available, enabling us to complete channel measurements for all emergent, scrub-shrub and forested wetland sites we have or will sample through 2007. When completed, these data will enable us to normalize all fish abundance estimates to densities per channel and drainage area dimensions and geomorphic indices.

Subtask 2.3.d. Estimation of physically-based habitat opportunity indicators

BPA is currently funding a comprehensive study to develop physically-based habitat opportunity indicators.

Proposed for FY 2006:

1. In this project we will continue to provide quality-controlled observations (Section 2.3a), which are needed to validate model simulations and habitat-opportunity metrics generated through separate funding.

Subtask 2.3.e. Use of modeling as a monitoring tool

Modeling, in the sense of the CORIE continuous forecasts and long-term simulation databases, is potentially valuable in guiding strategies to optimize observation networks. In this part of the project, we have historically used simulations generated through separate funding to periodically address the following questions related to the Cathlamet Bay monitoring network, in a low-level effort:

- Can CORIE simulations identify redundant observation stations, eventually leading to phasing out or relocating those stations?
- Can the CORIE forecasts help systematically prioritize the choice of location for any additional/alternative CORIE station in Cathlamet Bay?

Progress to date:

1. From annual climatologies of errors for CORIE simulation databases (1999-2005), we recommend starting in FY09 to reduce the number of observation stations – and their progressive replacement by simulations – for water levels, salinity and temperature. This will require a substantial investment in modeling in FY08.

Proposed for FY 2007:

1. We will discontinue low-level efforts to evaluate the extent to which modeling can optimize the CORIE observation network in Cathlamet Bay, in the expectation of a transformative modeling initiative in this FY08.

Task 2.4. Classify vegetation assemblage structure at each wetland site

We are characterizing vegetation assemblage structure at each wetland study site using the Lower Columbia River Partnership (LCREP)-generated classifications from remote sensing satellites (LANDSAT 7 ETM and panchromatic), and other sources (e.g., CASI hyperspectral, LiDAR). These classifications using remote sensing techniques and the delineation of vegetation assemblages as discrete "polygons" are verified "on-the-ground" using percent cover and other (e.g., shoot density, canopy cover) measurements to depict vegetation composition and relative abundance at each site.

Progress to date:

1. We have characterized plant vegetation (composition and frequency) immediately adjacent to our prey sampling sites at Russian, Seal, Karlson, and Welch islands.

Proposed for FY 2007:

1. We will survey vegetation at the tidal wetland sites at Wallace and Lord islands to characterize plant assemblage structure and composition. We will incorporate these results into our analysis of successional changes relative to historical wetland conditions. To insure consistency of the sampling protocol and continuity of the dataset, we will coordinate vegetation surveys with our tidal elevation sampling and continue involvement by graduate students from the University of Washington's Center for Urban Horticulture. As possible, we will coordinate with the LCREP forested tidal freshwater wetland ecosystem characterization that is being considered for BPA funding in 2007-2009.

Objective 3. Characterize historical changes in flow and sediment input to the Columbia River estuary and change in habitat availability throughout the lower river and estuary.

Long-term changes in river flow, salinity, tidal, and sediment transport regimes of the Columbia River and its estuary have had a profound effect on Columbia River salmonids and their habitat. Human influences include the hydropower system (the largest single factor), irrigation withdrawal, navigational development, diking and filling, and changes in land use throughout the basin. These human alterations interact with each other and are difficult to separate from the influence of climate. Climate processes include a long-term increase in temperature, a decrease (relative to the 19^{th} Century) in flow, and fluctuations in flow related to the Pacific Decadal Oscillation (PDO) and the El Niño-Southern Oscillation (ENSO) cycle. Understanding of the evolution of river-flow, salinity, tidal, and sediment-supply regimes in the Columbia River system will provide information to develop new management strategies, including those for the maintenance and restoration of shallow water habitats used by juvenile salmon.

Task 3.1. Climate and human effects on river flow and sediment input.

Attempts to restore salmon habitat in the Columbia River tidal-fluvial regime require that the interaction of basic physical processes (e.g., river flow, tides, and sediment input) with habitat be defined. It is also important to define and model the trajectory of physical changes over recent decades, and determine how this has influenced salmonids, their habitats, and the tidal-fluvial ecosystem as a whole. We will use available data, new analytical methods, and models to determine: 1) how changes in the salinity and tidal regimes affect habitat availability, 2) how river flow and sediment input to the system are related to climate and human alterations, and 3) how subbasin variations in climate and anthropogenic change affect lower river habitats.

Subtask 3.1.a. The interaction of tides, river flow, and shallow water habitat area.

This project approaches the above issues from the point of view that: a) data analyses are needed to address these issues, and b) simple models, especially those that are heavily constrained by data yet true to the underlying physics, are a cost-effective means to understand processes and guide management. Thus, this task uses innovative analytical methods and targeted models to determine how the tidal regime is affected by changes in flow magnitude and seasonality. River flow controls juvenile salmonid habitat availability directly by altering river stage, and indirectly by influencing tidal range. The daily power peaking cycle propagates downriver to the vicinity of Beaver, changing the character of the tide above Beaver, and affecting the timing of high and low waters. These processees are relevant to salmonids for several reasons. First, it is important that Chum redds immediately below Bonneville Dam remain underwater during certain key periods, and water elevations in this portion of the river are a function of both dam operation and the oceanic tidal influence. Second, tidal range affects habitat location and availability during juvenile salmon migration through the lower river and estuary. Alterations of seasonality and strength of the annual river flow cycle and especially the changes in volume and timing of the spring freshet mean that the annual cycle of tidal range has changed since construction of the hydropower system. The net result is that habitat for juvenile salmonids has been displaced in time and space. Habitat availability reaches a maximum earlier in the season than historically and has been relegated to lower elevations (and decreased in extent) by the reduction in river stage in spring. Its character has changed both because of the displacement, and because tidal range during spring has increased in response to the decreased flow and reduced friction on the tides propagating landward through the system.

Progress to Date:

1. We have established the response of river stage to flow throughout the lower-river and estimated the shallow water habitat area (SWHA) available every day for the 1974-1998 period in the reach between Skamokawa and Beaver (Kukulka and Jay 2003a,b).
2. We are now analyzing historic tidal data from, focusing on a spatially extensive 1940-43 data set collected when only one mainstem dam was operating (Bonneville). The 1940-43 data represents the best available description of pre-dam tidal behavior, and no subsequent study has provided such a high density of stations or an equivalent duration at multiple stations. Prior to March 2005, data from only 5 of 16 stations were made available to us by the National Ocean Survey (NOS), and even these stations had gaps. We now have the complete data set, and all stations have been digitized and analyzed. Examination of the 1940-42 data suggests that power-peaking was not a common practice at that time, and there was little regulation of the mean flow. Thus, comparing the 1940-42 data with contemporary observations will help us determine the effects of both power peaking and flow regulation. We also have found that the tidal regime was previously more responsive to river changes than it is at present. That is, a given increase in flow caused (historically) a larger decrease in tidal range than it does at present.
3. Analysis of the 1940-43 tide data in comparison to data collected after 2000 suggest that major and important changes have occurred in the tidal datum levels of the system. Not only is the tidal range growing (see below) but the Lower Low Water (LLW) and Higher High (HHW) levels have decreased for any given level of river flow. These changes are large (0.3 -1.5 m), depending on location, flow and datum (Jay and Leffler 2006a). These changes affect both navigation and salmon habitat:
    a. Navigation: vessel loading is limited during low-water periods that are more extensive than historically.
    b. Shallow water habitat restoration: flows are lower than they were historically, any given flow provides less SWHA, the habitat is displaced horizontally and vertically, and the habitat is more tidal.

   The observed changes have been caused by a combination of altered ocean tidal forcing, dredging, and channelization (Jay and Leffler 2006b).

4. Analyses of the strongly non-stationary tidal data in the Columbia pose a formidable methodological challenge. We continue to improve tidal analysis methods to meet this challenge. In previous years, we have implemented a "robust fit" method as an alternative to least-squares optimization, because "robust fit" is more effective with noisy, non-stationary data. (Jay et al. 2004). In the past year, we have made two improvements (Leffler and Jay 2006):
    a. River flow: we have developed a method to directly include river flow as a forcing variable in the tidal analysis, improving its statistical properties. This is an important improvement as we seek to document historical changes and understand underlying mechanisms
    b. New constraints: some Columbia tidal data sets consist solely of irregularly spaced-in-time high-low data (rather than evenly spaced hourly data), and other data sets have both hourly data and the extrema. Traditional tidal analyses have not used extrema data or have done so in only a minimal manner. We have included new constraints in our tidal analyses that recognize and used the extremal nature of high-low data. This is important because high-low data provide only four values per 25-hr tidal day, rather than 25 hourly values, greatly reducing the ability of a traditional analysis to extract tidal properties.

Proposed for FY 2007

1. In the coming year, we will continue to analyze and model the rapidly changing tidal processes, examining both changes in range and datum levels. This work should result in two papers based on Leffler and Jay (2006) and Jay and Leffler (2006b). These will be submitted to a dedicated volume in *Continental Shelf Research* stemming from the *Physics of Estuaries and Coastal Seas 2006* conference in Astoria in September 2006.
2. Analysis of shallow water habitat will be continued. This will involve extending the area analyzed upriver toward Vancouver, separating human and climate influences on SWHA, carrying out more detailed analyses of selected time periods of interest to the project, and incorporation of the LiDAR topography bathymetry. If LiDAR data are made available in a timely fashion, this will result in an update to Kukulka and Jay (2003a,b). A conference presentation will be made.

3. An archive of historical tidal height data will be posted on the web. Most of these data have been digitized from hard-copy, so that they are not otherwise available.

Subtask 3.1.b. Salinity intrusion, temperature effects and shallow water habitat.

This subtask uses available salinity, water and air temperature, flow, tide and bathymetric data to understand changes in estuarine salinity patterns, and in estuarine and fluvial temperatures. Understanding salinity intrusion length as a function of river flow, tides, and depth is important for restoration of shallow water habitat, because large, zero-salinity areas previously available to juvenile salmonids in spring are no longer available. Because of the loss of 1.2 years of funding for the OGI (now PSU) component of this project, we are not actively pursuing analyses of salinity intrusion at this time.

Higher water temperatures due to increased residence time of water in reservoirs and warmer temperatures may be a factor that affects the ability of juvenile salmonids to use available habitat. Therefore, water temperature data from The Dalles seaward have been analyzed in conjunction with air temperature data throughout the basin to understand how climate and flow regulation have affected water temperatures.

<u>Progress to Date:</u>

1. The Bonneville Dam scroll-case temperature record (1938-date) and sporadic temperature records for locations further downstream have been analyzed to understand the influence of climate and increased water residence time. We found that the river was considerably warmer for 1977 to ca. 1999 than even during the 1956-74 period when Hanford heat emissions warmed the river. While temperatures since 1999 have decreased somewhat, they are still higher than before 1956. Also, the number of months in which river temperatures are higher than those in the estuary has increased. Furthermore, high lagged correlations between Bonneville water temperature and prior air temperature in certain seasons now extend many months further into the past than was the case before ca. 1970. Both of these observations reflect the influence of increased water residence time in the system. The specific influence of climate was difficult to discern, but appeared to be smaller than that of reservoirs.

Proposed for FY 2007:

1. Further work will be carried out to separate climate and human influences on water temperature. We also will emphasize analysis of along-estuary temperature profiles that are available for some historical periods. NOS has now provided daily temperature data for selected years between 1854 and 1871. These will be compared to 20th Century data. We will incorporate these results in a conference presentation or in a synthesis paper prepared by our research team.

Subtask 3.1.c. Historical changes in quantity and quality of sediment input to the estuary.

We use historical accounts, and data collected by the USGS, Environment Canada, and the U.S. Army Corps of Engineers to understand changes in: (1) seasonality and amount of river flow, (2) the supply of fine and coarse material to the estuary, and (3) the quantity and quality of material supplied from selected sub-basins in relationship to climate change, catastrophic events, water withdrawal, and flow regulation. This task includes collaboration with the US Geological Survey in historical analyses.

Progress to Date:

1. In 2005, we used the newly derived, modified flow data (made available by BPA in the summer of 2004) to revise all previous (Naik and Jay 2005) observed, adjusted and virgin flow estimates for The Dalles. In 2006, this was extended to the Willamette and lower-river tributaries.
2. Changes in volume and timing of sand transport and total load at Vancouver have been partitioned between climate change, flow regulation, and flow diversion. Rating curves for sand and fines transport have derived for the Willamette at Portland; these rating curves were improved in 2006.
3. The flow record for the Willamette at Albany is only about 40% complete for 1878-1887 and missing for 1888-1892. Because the record for The Dalles begins in 1878, it is useful to complete the Willamette at Albany record for 1878-1892, so that a complete record for Beaver for 1878-date can be derived. Therefore, we used (2005) the existing data to derive a correlation between Albany river flow and precipitation at Corvallis (Portland before 1881) and hindcast the missing value, to provide a complete "estimated observed"

flow record. In 2006, these values were routed to Portland and used to derive observed, adjusted and virgin flow estimates for the Willamette River at Portland.

4. Using two Apprenticeship in Science and Engineeering (ASE) Students, we are systematically surveying available historic newspapers accounts of flooding for the period 1846-1877. We hope by the end of FY 2006 to have determined dates for all major spring freshets and to have compiled qualitative and quantitative accounts of weather during this period, at least for years with unusual flow events. We have found, for example, that the river was frozen from Cascade Locks down to the estuary for almost the entire period from 1 January to mid-March 1862, emphasizing the colder winter conditions during some 19th Century winters. Also, we found that in only two of the dozen years for which we have information regarding freshet timing (1841-1877) did the freshet occur in May. Most freshets occurred in mid to late June. This indicates that freshets were even later 1841-1877 than was the case 1877-1900.

Proposed for FY 2007

1. We will complete investigations of historic freshets and their contribution to sediment transport for ca. 1846-1877, resulting in a conference presentation. Estimates of annual average flows before 1878 and the resulting sediment input to the estuary will be indirect, because of the fragmentary nature of available data. We expect, however, to provide quantitative results with respect to changes in freshet volume and timing.
2. Estimates of the sediment input from Westside tributaries between Portland and Beaver (the Lewis, Kalama and Cowlitz) will be improved by incorporating data from the USGS NASQAN data base. Previous estimates were based only on data from the main USGS sediment transport data base (http://co.water.usgs.gov/sediment/). This improvement is necessary because of the paucity of data for these systems, and because of complications introduced by the Mt St Helens eruption of 1980.

Task 3.2. Evaluate the amount and character of fine and coarse sediment inputs to the Columbia River and estuary.

This task uses state-of-the-art optical methods to determine seasonal patterns in size distribution and concentration of sediment transported into the estuary. Coarse material plays a vital role in habitat maintenance and construction. Fine sediments contain organic matter that supports the estuarine food web, transports toxic materials, and causes turbidity that influences salmonid behavior and predation on salmonids. Much of the fine material in transport is actually in the form of aggregates, which are biologically active in the estuary. This task also includes collaboration with USGS with respect to sampling methods and monitoring at Beaver.

The instrument used in this task is a Laser In-Situ Scattering Transmissometer (a LISST-FLOC manufactured by Sequoia Scientific). The LISST-FLOC uses scattering of laser light to divide particles with diameters between 10 and 1500 microns into 32 size classes. The LISST-FLOC is unique in that it measures not just sand and fines, but also aggregates. When deployed at Beaver (RM-53) over the entire year and supported with suitable calibration studies, this instrument will allow determination of seasonal patterns of suspended sediment input to the estuary.

Progress to date:

1. The LISST-FLOC was deployed at Beaver from January to June in 2004, 2005 and 2006. Appropriate calibration data have been collected, and analysis of the results is ongoing. We concluded that we should mount the LISST in a horizontal (not vertical) position lower in the water column, despite greater logistical difficulties. An appropriate mount was constructed and installed in December 2005.
2. Suspended particulate matter is an important component of habitat, not just in the river, but also in the estuary and plume. Therefore, in spring 2004, 2005 and 2006, sampling was extended from Beaver to the Columbia River estuary and (with NSF support) to the Columbia River plume, to understand how particles are transformed as they move seaward (Chisholm and Jay, 2004, Spahn et al., 2006). Examination of LISST and other data suggest that most of the particulates originating in the river settled rapidly to the seabed in or near the estuary – most of the particles seen in the plume were biogenic. Particles were, however, concentrated in and beneath plume fronts (Horner-Devine et al., 2004).
3. We have examined the LISST data with a view toward determining a quantitative relationship between volume and mass concentration. We found that the relationship was seasonally variable – material in spring was less dense than in winter (Chisholm and Jay,

2004). This is expected, because of the larger amount of phytoplankton in spring. We need, therefore, to incorporate a chlorophyll measurement into the monitoring. We obtained data during moderate winter freshets in January and February 2006, allowing a fuller calibration of the instrument.

Proposed for FY 2007:

1. We will deploy the LISST-FLOC at Beaver during a large part of winter 2006-2007.
2. We will analyze our LISST measurements in combination with USGS optical backscatter data to provide, to the extent possible, actual suspended sediment transport estimates, partitioned by size (sand vs. fines). A conference presentation will result.

Task 3.3. Habitat change analysis

From FY 2002 through FY 2005, we completed a GIS project mapping the historical cover classes and shoreline for the entire estuary from the river mouth (Rkm 0 [RM0]) to Rooster Rock (Rkm 206 [RM128]). The historical cover classes were reconstructed from topographic surveys (T-sheets) conducted by the U.S. Coast and Geodetic Survey (USC&G) in the late 1800s. In addition, the digital maps provided the historic template for analyses evaluating changes in the geographic distribution, amounts, and classes of estuarine and floodplain habitat for juvenile salmonids completed in FY 2006.

In FY 2002, we developed a protocol to convert the historical USC&G survey maps to a workable GIS format. This enabled us to reconstruct the historical cover classes and landform from the surveys to generate a geographically correct and seamless coverage of the entire estuary at a resolution higher than available map data. In addition, we devised a protocol for habitat change analysis, comparing historic floodplain and estuarine conditions to recently classified satellite imagery made available through Columbia River Estuary Study Taskforce (CREST), Lower Columbia River Estuary Program (LCREP), and Earth Design Consultants, Inc, (EDC, Inc.). Initially, we selected four reaches in the estuary to serve as pilot sites for the habitat reconstruction and habitat change analyses. FY 2004 and 2005 tasks completed the reconstruction of historical cover classes for the entire estuary. In addition, we generated change analyses of the lower estuary from the mouth to lower Puget Island (Rkm 75).

In FY 2006, we developed and tested at two levels the spatial analysis methodology to quantify parameters, or metrics, of the estuary's historical characteristics. The first level examined landscape-scale metrics using cover classes. The next level of metrics applied a new hydrogeomorphic classification system, which was developed under a LCREP-funded project, to the historical habitat data. The LCREP hydrogeomorphic classification aggregates habitat cover classes, e.g. tidal marsh and mudflat, into hydrogeomorphic complexes. We could not conduct a change analysis with historical and contemporary datasets due to the 1 year delay of the LCREP dataset development and metrics, which are critical for our change analyses. All data products resulting from the GIS processes and analyses are accessible to CREST, LCREP, watershed councils, and local organizations in GIS and non-GIS format.

For FY 2007, we will conduct the second level of spatial analyses using the complex and landscape metrics to assess changes in the structure and arrangement of the estuary landscape from the late 1800s to 2001. In addition to the proposed spatial analyses, we will develop a Columbia River estuary project website to facilitate GIS and non-GIS data dissemination, project updates, maps, and contact information for project members.

<u>Progress to date:</u>

1. Developed an additional historical classification scheme for consistency with the LCREP Columbia River Estuary Ecosystem Classification, a hydrogeomorphic-based classification scheme, and the contemporary 2001 Landsat cover classes.
2. Developed landscape, cover class, and structure evaluation using detailed spatial analyses of historical datasets:
    a. Metrics were generated at the landscape, complex, and cover class level for juvenile salmon habitat
    b. Results complemented by analyses of the historical bathymetric data from the river mouth to Puget Island (Rkm 75) completed under a BPA-funded project
3. Developed narrative and other materials such as metadata describing the reconstruction of historical habitats and a method to disseminate GIS and non-GIS data generated from this project.

Proposed for FY 2007:

1. Evaluate landscape and habitat changes through detailed spatial analyses of historical and contemporary datasets:
    a. Change metrics will be generated for the lower estuary to assess the fragmentation/connectivity, dispersion, and complexity of juvenile salmon habitat and landscape structure. Analyses and results will not be complemented with the bathymetric changes from Puget Island (Rkm 75) to Bonneville Dam (Rkm 233) since the H-sheets above Rkm 75 will be digitized in FY 2007 as part of a BPA-funded project, and analyses will occur after FY2007 as a BPA-funded project.
2. Evaluate changes in the structure, arrangement, and connectivity of complexes across the estuary landscape.

Objective 4. Compile and disseminate data, analytical products and publications from research project

Although the many separate elements of this project generate data and analytical products that are unique to their respective tasks, the sampling designs, data collections, and reporting are also highly coordinated. Fundamental juvenile salmon data collected by individual project investigators are archived and accessible to all project personnel through an Access database maintained by NOAA-NWFSC. However, no dedicated server currently exists to disseminate the data, reports and products emerging from the research. Furthermore, many of the data we collect are specific to geographic locale but have not been incorporated into a spatially explicit GIS. We propose to develop a World Wide Web (WWW) site that will improve internal coordination among investigators while providing public access to new products and data. This will serve as a focal point for information on the project's goals, objectives, and participants, with appropriate contact information, as well as (downloadable) access to available data and GIS datasets.

Data availability will follow the guidelines and protocols of the NSF Long-term Ecological Research (LTER) Network[1]. A restricted, password-protected access portal will allow project investigators and other authorized researchers to download non-public information, such as draft reports, preliminary analytical results, and other research products. In addition to the password

[1] See:http://www.lternet.edu/data/netpolicy.html

protected portal, project reports, theses, publications and other narrative materials will be available for download by the general public. All data with spatial context, e.g. location data of sampling sites collected with a Global Positioning System (GPS), will be spatially referenced in GIS and made available as a geodatabase or maps to both internal investigators and the public. For rapid and concise data dissemination, we intend to use an interactive map-based search tool that will allow selection of data and other information by estuary location.

Task 4.1. Develop and maintain project WWW site for the coordination and dissemination of project data, reports, and other products.

In FY2005-2006, the University of Washington planned to develop and maintain an interactive Internet site that will facilitate coordination among project investigators; allow archiving and distribution of data, images, maps and other graphics and analytical results; and provide access to project products. However, this task was delayed until FY 2007 due to reduction of funds.

Progress to date:

1. The development of a project website for GIS-data, non-GIS data, and report dissemination was not created in FY 2006 due to the reduction of funds

Proposed for FY 2007:

1. Meet with project investigators to develop the goals and purposes of the website
2. Design website in consultation with other designers of model websites;
3. Develop interactive, geographic-based search tool;
4. Compile data, reports, images, maps, presentations, and other products for web access;
5. Test website performance with project investigators, and revise according to feedback;
6. Establish investigator access to restricted site; and,
7. Post website for public access.

Fish Requirements for FY 2007

We plan to periodically sample fish primarily in the shallow water habitats of the lower and mid-Columbia River and estuary (upriver to Rkm 101 at Lord Island) and will use the existing population of juvenile residents and outmigrant salmon. The sampling will focus on catch-and-release to determine presence and abundance in the various habitats sampled. A subset of the captured fish will be sacrificed to obtain measures of performance (growth, condition, food habits, etc.).

Schedules

We are conducting the estuary study in multiple phases. The first year focused on identifying habitat sites for assessments and testing feasibility of sampling gear to capture juvenile salmon, selecting and positioning physical monitoring stations, beginning the historic reconstruction of flow and sediment input into the lower Columbia River and estuary, and analysis of historical habitat conditions. The second year included data collection, historic reconstruction of flow and sediment, and habitat-change analysis in the lower estuary. We continued field data collection in years 3 and 4, developed analytical protocols for life-history analyses from scales and otoliths, and began the first laboratory analyses of selected fish and invertebrate samples. Field and laboratory activities continued in Year 5, but new feasibility studies were conducted to test: (1) mark-recapture methods for estimating Chinook residence times in emergent marsh habitats, and (2) whether established trapnet methods are appropriate for sampling other wetland habitat types located further upriver above the Cathlamet Bay region.

Based on the priorities established at the January 2005 project meeting and the success of preliminary marsh residency studies in April - May 2005, we began adjusting monitoring activities (1) to model and assess fish performance in different wetland habitat types and successional stages, including diverse areas of the tidal fresh region above Cathlamet Bay; and (2) to investigate the broad-scale distribution of upriver source populations and life-history types that enter and utilize different portions of the estuary landscape. Toward these ends, residency and consumption studies were completed in 2006 at two locations within the Russian Island channel network, evaluating the benefits of the Cathlamet Bay emergent marsh complex for subyearling Chinook salmon. At the same time, we established new beach seine and wetland survey sites upriver in the vicinity of Wallace Island and Lord Island. In 2007 we propose to continue a second year of monitoring at Wallace and Lord Island sites in the mid estuary. We also will assess whether additional consumption and residency studies, similar to those conducted at Russian Island study in 2006, can be implemented at one of the emergent/scrub-shrub/forested sites at Wallace or Lord Island. Feasibility will depend on channel depths and fluctuations in river flow, whether ongoing monitoring in the lower estuary must be reduced substantially to support these studies, and whether a remote PIT detection system can be successfully deployed to minimize manpower requirements upriver. These decisions will be made before or during the 2007 annual project meeting.

To support data synthesis by research team members and to allow dissemination of project results to the public, we will begin developing an interactive project website in 2007. In 2008 field activities will be reduced to a minimum maintenance level to emphasize data synthesis and publication and to prepare any new proposals for estuarine studies beyond the current proposal period.

Project Impacts, Facilities, and Equipment

Mooring sites and instrumentation will be needed to supplement the necessary physical monitoring of conditions in the Cathlamet Bay region. No impacts to listed ESU's are expected from the activities associated with this proposal.

Project Personnel and Duties

1. Program Manager – Edmundo Casillas
2. NOAA Fisheries Project Leaders – Daniel Bottom and Curtis Roegner
3. Monitoring salmon habitat use and abundance – Curtis Roegner and Susan Hinton
4. Identifying salmon-habitat associations – Daniel Bottom and Si Simenstad (University of Washington)
5. Climatology and sediment inputs – David Jay (Portland State University)
6. Historical habitat reconstruction and website development – Jennifer Burke (University of Washington)
7. Physical monitoring – Antonio Baptista (Oregon Health & Sciences University)
8. Trophic relationships (Jen Zamon (NOAA Fisheries)
9. Otolith microstructure and scale analyses – Lance Campbell and Steve Schroeder (Washington Department of Fish and Wildlife).

Technology Transfer

Technology transfer will be in the form of written and oral research reports. In January 2004, we organized the first annual estuary project review: (1) to share preliminary findings with project cooperators and research staff, (2) to synthesize and integrate results from our diverse research activities, and (3) to prepare detailed sampling schedules for the upcoming field season. The third annual review meeting was held in January 2006. Project results to date were synthesized and presented at the Columbia Estuarine Research Conference in Astoria in April 2006. Draft reports of annual progress will be provided to the COE by 15 December each year, and final annual reports will be provided by 15 March the following spring. Results will be published in appropriate scientific journals.

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